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SPREAD AND INFESTATION BY THE EUROPEAN
CORN BORER DURING 1926¹

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The season of 1926 was marked not only by a great extension of the territory occupied by the European corn borer (*Pyrausta nubilalis* Hbn.) in the Great Lakes region, but also by an alarming increase in the severity of infestation and damage as compared with 1925. During this same period an important reduction in corn-borer infestation occurred in New England, an area where severe damage by the pest reached its high peak in 1922.

This circular is intended to inform corn growers concerning the details of the situation and to recommend control procedure for the spring work, particularly in areas where the corn borer may be expected to increase in 1927 unless such control practices are adopted universally.

Previous circulars in this series² have explained important methods for reducing existing infestation and have discussed briefly the habits of the borer, quarantine and scouting methods, parasites, and similar subjects.

¹The Bureau of Entomology and the Federal Horticultural Board, United States Department of Agriculture, cooperating with State departments of agriculture.

²CAFFREY, D. J., and WORTHLEY, L. H. HOW TO FIGHT THE EUROPEAN CORN BORER THIS FALL. U. S. Dept. Agr. Misc. Circ. 84, 4 p., illus. 1926.

WORTHLEY, L. H., and CAFFREY, D. J. TIMELY INFORMATION ABOUT THE EUROPEAN CORN BORER. U. S. Dept. Agr. Misc. Circ. 70, 8 p., illus. 1926.

SCOUTING AND QUARANTINE OPERATIONS ARE IMPORTANT MEANS OF CONTROL

Human agency is a dangerous and most important factor in the spread of the European corn borer. Commerce in corn and its transportation by man afford great opportunity for the spread of the pest. Because of this fact strict quarantines have been declared to prevent the movement of products likely to be infested by the corn borer from infested to noninfested areas.

In order to maintain a basis for these quarantines, it is necessary each year to conduct scouting operations in the regions adjacent to those previously quarantined, and elsewhere. A large force of men is employed each year in this work, and during 1926, 525 townships were found to be newly infested. These operations were conducted both in the New England States and in the Middle Western States.

In the New England area only two additional townships were found to be infested in 1926. There the spread of the European corn borer has been extremely slow for the past four years.

In addition to the scouting around the border of the quarantined area in the Middle Western States, scouting was done along main highways in Indiana and along the main highways for a distance of about 40 miles from the city limits of Chicago to determine whether isolated infestations were present. None was found this season in such outside areas. The program for 1927 includes more extensive outside scouting in the Corn Belt States. During the season of 1926 approximately 140 uninfested townships were scouted. In 1926 the insect was found for the first time in Indiana and West Virginia. The most westerly edge of the infestation in Michigan is about 20 miles from the eastern shore of Lake Michigan.

The quarantine work, as conducted by the Bureau of Entomology in cooperation with the Federal Horticultural Board and the various States affected, began originally in the New England area, where two generations of the pest occur annually. In this area the quarantine includes corn, broomcorn, sorghums, and Sudan grass, cut flowers or entire plants of chrysanthemum, aster, cosmos, zinnia, and hollyhock, and cut flowers or entire plants of gladiolus and dahlia, except the bulbs thereof, without stems, and applies throughout the entire year; to celery, green beans in the pod, beets with tops, rhubarb, and oat and rye straw, the quarantine applies from June 1 to December 31 of each year. Chrysanthemums and gladioluses may be heavy carriers of the corn borer and are shipped long distances. Quarantine stations are established at Boston and Worcester, Mass., Providence, R. I., Portland, Me., and Durham, N. H., in the New England area. Inspectors are detailed from these stations to make inspections and certifications in the larger wholesale markets. Numerous inspections are also made in the field at the flower grower's place of business.

In the single-generation area, extending from the western edge of Vermont westwardly to Indiana, the quarantine includes only corn, broomcorn, sorghum, and Sudan grass. The other products quarantined under the New England regulations have not been found sufficiently infested to warrant their inclusion in the quarantine applying to the western area. The chief effort is directed against the

transportation of corn on the cob from the quarantined area to points outside thereof, because ears of corn often are dangerously infested. In maintaining this quarantine, inspectors are stationed on all main highways leading out of the quarantined area and are instructed to stop all vehicles in order to ascertain whether they are carrying corn on the cob. In Pennsylvania, Ohio, and Michigan, during the summer of 1926, 100 roads were patrolled and approximately 2,000,000 automobiles were stopped. From these cars 138,532 ears of corn were taken, and many of these were found to be infested, containing from one to five borers each. By these means dangerously infested material was prevented from going to Iowa in three instances and

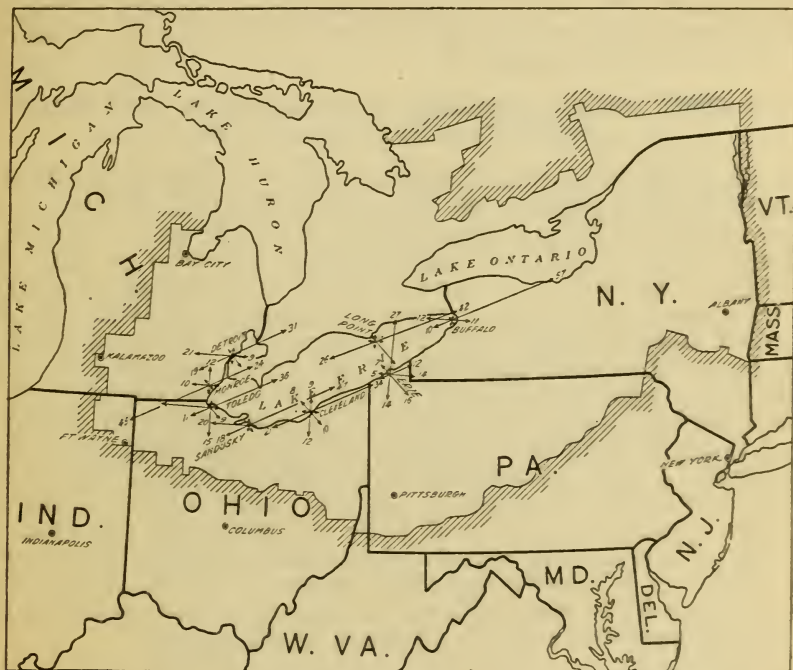


FIG. 1.—Direction of wind and percentage of wind movement from each point of the compass in the region of the Great Lakes during the flight period of the European corn-borer moths, July, 1926. The broken line shows the limits of the quarantined area to January 1, 1927. The approximate limits of infestation in Ontario and Quebec are shown in the same manner.

to Florida in two instances. A large number of ears were intercepted en route to Chicago, Ill., and parts of Indiana. Serious and extensive long-distance spread of the European corn borer was thus prevented by the operation of quarantine No. 43.

In addition to the quarantined products previously mentioned, shelled corn has recently been included in quarantine No. 43. The requirements for certification of shelled corn are that it be free from all parts of the cob. This should insure its leaving the quarantined area free from any infestation of the European corn borer and thus safe for movement to outside points.

The railroad, steamboat, and other transportation agencies are frequently visited by inspectors in search of possible violations of

quarantine No. 43. Dining cars are forbidden to carry roasting ears through or out of infested areas.

If good cooperation can be secured from all concerned in observing the regulations regarding the transportation of quarantined products, commercial spread can be reduced to a minimum.

The area now quarantined on account of the European corn borer in the two-generation area, which includes New England and the vicinity of New York City, covers 6,461 square miles. The one-generation area, extending from the western boundary of Massachusetts through New York and including Pennsylvania, Ohio, Michigan, Indiana, and West Virginia, comprises 87,325 square miles, and the total for the entire area under quarantine is 93,786 square miles. The limits of the quarantine to January 1, 1927, in the one-generation area (as previously explained) are shown by the broken line on the map (fig. 1).

THE CORN BORER INCREASED ALARMINGLY IN THE MIDDLE WESTERN AREAS DURING 1926

During 1926 a survey of European corn-borer conditions in Michigan, Ohio, Pennsylvania, and western New York showed that there were nearly four times as many borers, on an average, in these four States as were found in a similar survey conducted in 1925. In Michigan there were over seven times as many borers as in 1925, in Ohio nearly three times as many, in Pennsylvania about two and one-half times as many, and in western New York the number was increased by more than one-half the former number (Table 1). This survey was conducted just prior to the harvest season in alternate townships within the infested area, systematic field examinations being made in five separate and representative fields of each township. A total of 1,035,300 corn plants in 2,071 fields (13,535 acres), located in 415 townships, were examined for corn-borer infestation during the survey of 1926. Of the stalks examined an average of 2.95 per cent were found to contain the borer and to have an average of 2.72 borers per infested plant, or an average of 8.03 borers for each 100 plants (Table 1). The noninfested as well as the infested plants were counted in computing the averages.

TABLE 1.—*Comparison of the results of the field surveys of 1925 and 1926 for the European corn borer in New York, Pennsylvania, Ohio, and Michigan*

Area	1925			1926			Percentage increase in—		
	Average percentage of stalks infested	Average number of larvæ per infested stalk	Total larvæ per 100 stalks	Average percentage of stalks infested	Average number of larvæ per infested stalk	Total larvæ per 100 stalks	Average percentage of stalks infested	Average number of larvæ per infested stalk	Total larvæ per 100 stalks
New York.....	1.56	2.87	4.48	3.18	2.20	7.00	103.8	123.3	56.3
Pennsylvania.....	1.28	2.68	2.67	1.92	3.43	6.60	50.0	64.9	147.1
Ohio.....	1.48	1.29	1.80	2.17	2.49	5.40	46.6	93.1	184.2
Michigan.....	1.10	1.36	1.50	3.72	2.87	10.67	238.2	111.0	611.5
Total area.....	1.35	1.56	2.11	2.95	2.72	8.03	118.5	74.4	280.5

¹This figure represents the percentage of decrease in larvæ per infested stalk during 1926 as compared with the number in 1925.

An analysis of this survey based upon the increase per township showed that the increases were well distributed throughout the infested area and that they occurred with equal frequency and in about the same degree in the townships along the margins of Lakes Huron, Erie, and Ontario as in the townships on the higher ground at a distance from the Lakes.

In order to estimate the progress of infestation from year to year in that portion of the Ohio area where the corn borer was first found in 1921, a separate survey has been made each year. During 1926 a survey showed that there were five and one-half times as many borers present in 192 representative fields of this area as were found in a similar survey in the same or near-by fields during 1925. Compared with a similar survey in 1923, there were nearly 15 times as many borers in this area in 1926 as there were in the same or near-by fields in 1923.

A similar survey to determine the progress of infestation in the first infested area of western New York, bordering Lake Erie, showed that two and three-fourth times as many borers had developed in 53 fields of this area during 1926, as compared with the number shown in a survey of the same or near-by fields in 1925. As compared with the 1923 survey, the 1926 survey showed over 12 times as many borers in this area in 1926 as there were in the same area four years ago.

The preceding figures relate to infestation in the entire corn plant, but similar increases of infestation were noted in annual examinations made of the ears in the western New York area. During the period 1921-1926, inclusive, examinations were made in several representative fields and at various canning factories in the Silver Creek, N. Y., area to determine the extent of infestation in ears of sweet and field (dent) corn. Whenever possible the same fields were used each year. The results are shown in Table 2.

TABLE 2.—*Progress of European corn-borer infestation in corn ears in the western New York area*

Year	Number of ears examined	Percentage of ears infested	Annual increase	Year	Number of ears examined	Percentage of ears infested	Annual increase
			<i>Per cent</i>				<i>Per cent</i>
1921.....	1,400	1.50		1924.....	12,000	9.04	64.3
1922.....	10,182	2.80	86.5	1925.....	18,879	11.60	28.3
1923.....	11,650	5.50	96.4	1926.....	13,395	25.43	119.2

Table 2 shows that in the western New York area, from 1921 to 1926, inclusive, about 17 times as many ears were infested as were infested in 1921.

In the first infested area of eastern New York, centering at Schenectady, the infestation was over four times as heavy in the 30 fields examined during 1926 as that shown in a similar survey of the same or near-by fields during 1924. No surveys were made in this area in 1925 or in 1923. The 1926 records show that more than five and one-half times as many borers were present in this section in 1926 as in 1922.

The alarming increases detailed above show very plainly that unless prompt and heroic measures are taken to control the borer,

serious and widespread losses may occur in these areas in the very near future.

THE CORN BORER DECREASED IN NUMBERS IN THE NEW ENGLAND AREA DURING 1926

An encouraging development during 1926 was the reduction in the number of borers in the New England area. The 1926 survey, conducted as previously described, showed that a reduction of 38 per cent had occurred in 223 cornfields of 46 representative townships, as compared with the results of a similar survey during 1925. Of the plants examined in 1926, an average of 14.3 per cent were infested, the number of borers per infested plant being 2.1, or an average of 30 borers for each 100 plants in the cornfields examined. Noninfested as well as infested plants were counted in arriving at these averages. Most of the fields examined in this area were of necessity sweet corn, since very little corn is grown for grain in that part of New England.

As compared with the results of a similar survey in 1922, a reduction of 94 per cent of the infestation was shown to have taken place in the cornfields of this area during the last five seasons. This means that there were only approximately one-sixteenth as many borers in this area during 1926 as there had been in 1922.

A special survey to determine the ear infestation in 41 fields of sweet corn in the New England area during 1926 showed that, of the ears examined, an average of 6 per cent were infested. As compared with the results of a similar survey in 1925, a 10 per cent reduction in the ear infestation was shown to have occurred during the last year. Comparing results from 1922 (the first year this special survey was made) with those in 1926, a reduction of 71 per cent was shown to have taken place in ear infestation during the last five seasons.

Reductions similar to those on corn were recorded in the corn-borer infestations of vegetables, field crops, flowers, and weeds.

This reduction of infestation in New England has been brought about principally through the general observance of the Massachusetts clean-up regulations plus the educational effect of destructive outbreaks of the corn borer in the past. Adverse weather conditions for the development of the corn borer during the period 1923-1926 and increased activity of natural enemies, particularly a native egg parasite, have also contributed to this result.

Now that the European corn borer in the infested area of New England is at a very low ebb, the clean-up efforts in this area should be continued even more thoroughly in order to retain the advantages already gained and to secure further reductions in infestation and loss.

DISKED CORN STUBBLE IS AN IMPORTANT SOURCE OF INCREASED INFESTATION

Much of the increase in corn-borer infestation which developed during 1926 in the area bordering Lake Erie may be charged to the common practice of disking small grains in high corn stubble and stalks. This source of increased infestation can be eliminated, or

greatly reduced in importance, by confining disking operations to fields where corn stubble and surplus stalks have been properly treated. Stubble pulverizers (fig. 2) can be employed to destroy corn stubble not more than 14 inches high. Where this procedure is not possible the stubble could be poled down, raked into windrows, and burned, or, if that can not be done, the field should be plowed clean. The destruction of such infested material is certain to reduce greatly the borer population in each field treated. It removes the ideal shelter otherwise afforded the corn borer by the numerous corn remnants that remain on the soil surface after disking.

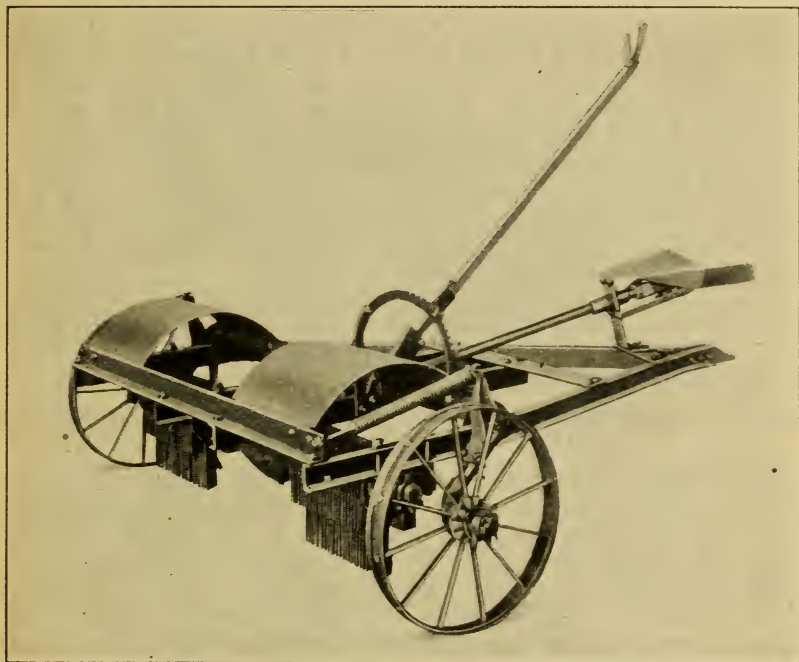


FIG. 2.—A stubble pulverizer, designed to destroy corn stubble not over 14 inches in height in fields infested by the European corn borer

CORN STUBBLE FROM THE CROP OF 1926 IS DANGEROUSLY INFESTED

An examination of 43 fields of corn stubble, totaling 338 acres, in the Bono Reno section of northwestern Ohio during the late fall of 1926 showed that an average of 8.91 per cent of such stubble was infested by the corn borer at the rate of 9.83 borers to each 100 corn stubs in the field, based upon an average of the samples examined. In the worst infested fields examined 29.6, 25.4, and 25.2 per cent, respectively, of the stubble was infested. Averages were computed from noninfested as well as infested stubble. The foregoing figures show an increase of 21 per cent in the number of borers remaining in the stubble as compared with the number found in the course of a similar examination in the same general section during the late fall of 1925. In the 43 fields the corn stubble ranged from 4.5 to 15.9 inches in height, the average being 9.29 inches. This is a reduction of about 4 inches as compared with the average height of stubble

in the fields examined in 1925. Ten of the fields were machine cut, 4 were cut partly by machine and partly by hand, and 29 were cut by hand. Five hundred corn stubs were cut open in each field, and from these examinations it was estimated that there were about 319,388 borers in the stubble of the fields examined, or an average of 944 borers in each acre of corn stubble.

In a similar examination of 27 corn-stubble fields, totaling 155 acres, in the Sandusky, Ohio, section during the late fall of 1926 an average of 7.32 per cent of the stubble examined was found to be infested by the corn borer at the rate of 8.27 borers to each 100 corn stubs in the field. In the worst infested fields examined 32.8, 23.8, and 22 per cent, respectively, of the stubble was infested. In the 27 fields the corn stubble ranged from 5.5 to 22.9 inches in height, the average being 12 inches. Twenty-two of the fields were hand cut and five were machine cut. Five hundred corn stubs were cut open in each field, and from examining these it was estimated that there were about 122,576 borers in the stubble of the 27 fields, or an average of 793 borers to each acre of corn stubble. In nine of these fields in which the cornstalks had been examined before they were cut it was determined that 18.76 per cent of the total borers in the entire plant were left in the corn stubble.

It is evident that unless the number of borers left in the corn stubble of these and of similar fields is greatly reduced by the recommended control measures a marked increase in corn-borer infestation may be expected in 1927.

WEEDS IN THE MIDDLE WESTERN AREAS CARRIED INCREASED INFESTATION DURING 1926

Host plants other than corn in the middle western areas were found to contain many more borers during 1926 than in any previous year. This development is due principally to the general increase in number of borers throughout the area and to the development of severe infestation in certain parts of the area. In the vicinity of Silver Creek, N. Y., during early November a careful examination of the more common large-stemmed weeds growing in and near severely infested cornfields revealed that infestations affecting from 20 to 96 per cent of the plants examined had developed in foxtail, pigweed, lamb's-quarters, panic grass, cocklebur, and barnyard grass.

In the Bono-Reno area of northwestern Ohio from 12 to 78 per cent of the pigweed, lamb's-quarters, panic grass, cocklebur, and smartweed examined in November, 1926, contained the borer. These weed infestations were found in and near severely infested cornfields. No infestations in such plants were found at a distance from corn.

As a result of previously obtained information, it is certain that large-stemmed weeds and grasses, when growing in or near cornfields severely infested by the corn borer, should not be neglected in clean-up operations. The fact should be emphasized that these weed infestations in the Middle West at present are confined to severely infested cornfields or their margins. All heavy weed growths along field margins should be burned or otherwise disposed of and a general attempt made to reduce corn-borer infestation to a point where such borers as remain will be confined to corn. Efforts should be made, therefore, to keep the European corn borer at what may be termed a medium infestation. Under these conditions the borers are confined

for the most part to corn plants, and the probability of effective mechanical control at harvest by the use of low-cutting corn binders, portable silage cutters, etc., is greatly increased.

THE WIND CARRIES CORN-BORER MOTHS

Field experiments have shown that much of the spread of the corn borer is due to the flight of the moths. It has been determined by careful experiments that the moths can fly at least 20 miles in a single flight or in a series of flights. It is plain, therefore, that the presence of millions of borers in the cornfields along the margin of Lakes Huron, Erie, and Ontario (in Michigan, Ohio, Pennsylvania, and New York, and also in Ontario, Canada) presents a serious menace to the more lightly infested territory farther back from the Lakes as well as to the adjoining area not yet known to be infested.

A probable example of the spread by the flight of moths from heavily infested areas is the spread during 1926 of many corn borer moths from the intensely infested areas in the Province of Ontario, Canada, particularly from Essex and Kent Counties, to the United States side of Lake Erie. Undoubtedly moths played a very important part in the great spread and increase in intensity of the corn-borer infestation in Michigan, Indiana, Ohio, Pennsylvania, and western New York during 1926. In order to learn more about this matter, a study was made of the direction of the winds in the Lake Erie region during July, 1926, the period during which the moths were in flight. From wind records taken by the Weather Bureau at Detroit and Monroe, Mich., Toledo, Sandusky, and Cleveland, Ohio, Erie, Pa., Buffalo, N. Y., and Long Point, Ontario (fig. 1, p. 3), it may be seen that an unusual amount of wind movement occurred from Ontario to the United States side of Lake Erie during the flight period of the moths in 1926. During windy periods the direction of flights is with the wind. Since the moths are known to fly a distance of at least 20 miles, and inasmuch as they are able to alight upon the surface of the water and again take flight, it seems likely that the prevalence of favorable winds during July, 1926, aided them in their flight across the lake.

In explanation of the arrows and figures shown in Figure 1 it should be stated that the percentage of total wind movement during July, 1926 (in miles), from each point of the compass, at each of the designated weather stations, is shown by arrows and by figures at the points of such arrows. Each arrow represents by its comparative length the percentage of wind movement (in miles) which came from that particular direction. Arrows for which figures are not shown can be compared with arrows for which this information is given. Although the moths usually fly at night and are more active during the first three or four hours of the night than at other hours, a comparison of direction and velocity of the winds during the night and during the hours of daylight showed no great difference. Moreover, it is not known whether the conditions of extended flight are limited to the hours at night. The figures given are therefore those representing the wind movement during the full 24-hour period and each day of the month in question.

Another indication of the importance of the flight of moths from severely infested areas to outlying districts is seen in connection with

infestations in New England. During the period prior to 1922 a rapid spread of the corn borer occurred each year in that area. Since 1922, however, the severity of the corn-borer infestation in New England has declined each year, and during the last four seasons very little spread has occurred on the margins of the area.

It is therefore logical to advocate that special efforts be made to clean up severely infested areas in order that the spread of corn borers by the flight of moths from such areas may be greatly reduced and in order that the borer population and consequent injury in the areas cleaned up may be reduced at the same time.

CORNSTALKS STORED IN BARNs ARE A DANGEROUS SOURCE OF INFESTATION

In experiments in which cornstalks infested by the corn borer were stored in a barn at Sandusky, Ohio, during the fall of 1925 and kept thereafter under dry conditions a total of 54 per cent of the borers changed to moths and emerged during or before the last week of August. About half of this number emerged between August 7 and August 13.

Continuing the experiment, it was found that the eggs deposited on growing corn plants by the late-emerging moths hatched readily and that the percentage of resulting larvæ establishing themselves in the plants and reaching full growth averaged about the same as the percentage from eggs deposited earlier in the season.

From this and similar experiments and field observations it may be seen that corn-borer moths emerging from material stored in barns and similar structures may be an important means of reinfesting late corn, and that such moths must be considered as a part of the general infestation which must be destroyed before the issuance of moths the following year. The necessity for destroying such stored cornstalks is obvious.

SHREDDERS AND SILAGE CUTTERS HAVE BEEN FOUND VERY EFFECTIVE IN TREATING INFESTED CORNSTALKS

Numerous and extended experiments with standard-type husking machines equipped with shredder heads, cutter heads, or combination shredder and cutter heads showed that this method of disposing of infested fodder was very effective in killing corn borers. Where sufficient tension was maintained on the snapping rolls to produce a crushing effect on the cornstalks an average of 98 per cent of the borers were killed by the machine. This figure does not include the additional kill obtained in the process of storing the shredded material, feeding it to livestock, and using the residue as bedding to be ultimately trampled into the manure.

Special experiments with silage cutters showed that cutting infested cornstalks in lengths of three-eighths of an inch, five-eighths of an inch, and three-fourths of an inch, respectively, killed 100 per cent of the borers in the treated stalks. Some of the borers escaped destruction when the stalks were cut into pieces exceeding three-fourths of an inch in length. However, all silage-cutting machines used in corn-borer territory should be designed and adjusted for not more than a half-inch cut to insure a 100 per cent kill of borers and to provide a proper margin of safety.

The use of huskers and silage cutters is strongly recommended for the disposal of fodder, and their use in corn-borer territory should be greatly extended.

LATE-PLANTED CORN MAY BE INFESTED LATE IN THE SEASON

That corn borers hatching from eggs deposited by corn-borer moths on late-planted corn late in the season will reach full growth in significant numbers was indicated by experiments at Silver Creek, N. Y., during 1926. In these experiments the moths were confined in temporary cages during the last week of July over dent corn planted on June 30. The borers hatching from eggs deposited by these moths had reached full growth (maturity) on September 20, when the plants were examined. In this case the percentage of borers which had established themselves in the plants, compared with the total number of eggs deposited on the plants, was 10.9. A series of sweet-corn plants, in a duplicate experiment, gave a percentage of borer establishment of only 4.2.

In a similar experiment at Sandusky, Ohio, 11.1 per cent of the eggs deposited on dent-corn plants on July 29 had reached full growth on September 6, when the plants were examined. In this case the corn was planted June 14, and the plants varied from 15 to 18 inches in height when the experiment started.

Emphasis should be placed upon the fact that these experiments were conducted under artificial conditions and that the results show merely the ability of the corn borer to infest corn successfully and to reach full growth before the end of the season, when eggs are deposited upon late-planted corn late in the season.

INCREASED WORK HAS BEEN DONE WITH FOREIGN PARASITES OF THE CORN BORER

Up to and including the month of October, 1926, a total of about 225,000 foreign parasites were liberated in nine different locations in the corn-borer-infested areas of Michigan, Indiana, Ohio, Pennsylvania, and New York. Seven distinct kinds, or species, were used in this work. Definite evidence has been obtained that two of these species have started to prey upon the corn borer in Ohio, and at least one species is known to have become established in western New York.

In New England a total of about 1,187,000 of these foreign parasites have been placed in the infested cornfields. Ten different kinds, or species, were used in New England, and five of these species are known to have become established as natural enemies of the corn borer. In certain fields of this area careful collections have shown that the total parasitism by the foreign parasites exceeds that by the native species.

The rate of importation of foreign parasites from Europe has been greatly increased, and preliminary shipments of foreign parasites from India and from Japan have been received.

These extensive shipments of parasites from abroad, plus the increased numbers of parasites reared in the laboratory, will be used during the spring and summer of 1927 to reinforce the colonies of parasites already in operation and to start new colonies at strategic points.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

April 6, 1927

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